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ADP014978

TITLE: On the Nature of the Voltage Fluctuations in the Plasmatron with Self-Established Arc Length

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TITLE: International Conference on Phenomena in Ionized Gases [26th] Held in Greifswald, Germany on 15-20 July 2003. Proceedings, Volume 4

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On the Nature of the Voltage Fluctuations in the Plasmatron with Self-Established Arc Length

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In a plasmatron, when the cathode is placed centrally, the channel wall serves as an anode, and length of an arc is self-established, voltage fluctuations have a specific ramp-like shape. This shape of the voltage fluctuation has the regular component generated by downstream elongation of the electric arc and its consequent rerouting and a noise generated by different processes going on inside the plasmatron [1-5]. The downstream elongation of the electric arc explains the first slow stage of the voltage fluctuation. The second stage – a steep fall of the voltage – is explained by the electric breakdown between the hot arc core within the axis and the anode spot on the plasmatron channel. The "breakdown" observed during the self-establishment of the arc length in the flow occurs mainly under the influence of dynamic interaction of electric currents of the different parts of the arc.

The displacement of the anode end of the arc when the cathode end is fixed to its central place at the conical cathode must generate without fall fluctuations of the current path near the position of the unstable equilibrium under the influence of the Ampere force. The velocity of the plasma flow is maximal at the axis, so the part of the current channel is entrained downstream while the "fastening" point at the anode, where the arc ends, lags behind because the plasma has zero velocity at the wall. The entertainment and the elongation of the arc in the downstream direction raise the length of the current path by $\delta l(t)$ and the arc voltage by $\delta U(t) = E_l \delta l(t) = E_l V(r = 0)\, t$, $E_l \approx$ Const. The displacement of the far end of the current path from the axis wakes up an interaction of different parts of the current channel – the radial Ampere force appears that was absent before. The interaction of anti-parallel currents from different parts of the current path leads to the rerouting of the anode end of the arc. This shunting process makes the arc voltage lower. It is very fast compared with the stage of linear increase of the voltage.

The dependency of the main fluctuation frequency on external parameters assuming that the electric arc shunting process in a plasmatron with gas flow and self-established arc length is determined by electrodynamic interaction of the currents from different parts of the current path may be found. We define the characteristic fluctuation frequency as:

$$f = \frac{d(kG)}{dt}/G, \qquad (1)$$

where $k(t) = 2\pi \iint \rho V r dr / G$.

The characteristic fluctuation frequency could be found from the dynamic equation of an arc and for arbitrary values of the magneto hydrodynamic interaction parameter (MHDIP) $N = jBd/P$ may br represented in the next form:

$$f = \xi_1 I^2 \mu_0 / Gd \quad + \xi_2 G / \rho_0 d^3 =$$

$$= I^2 \mu_0 / Gd \,(\xi_1 + \xi_2 / N). \qquad (2)$$

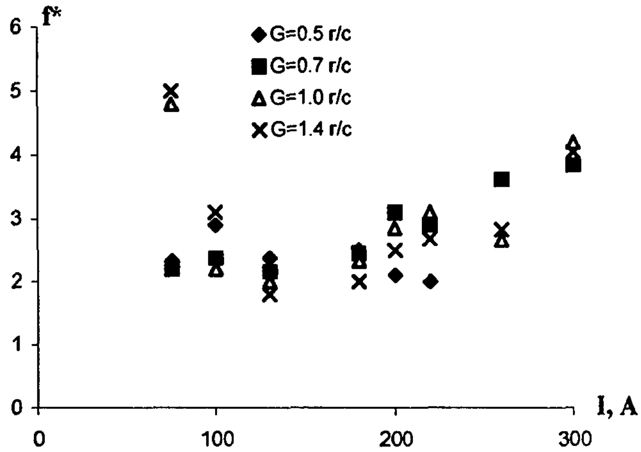
Here ξ_1, ξ_2 are a non-dimensional coefficients. The coefficients ξ_1 and ξ_2 depending on the geometric factors differ from 1. They can be calculated using the numerical solution of the non-stationary 3D magnetogasdynamic problem for the arc shunting or determined from the experiment. Numerical solution of this non-stationary 3D problem is also a hard problem so we have obtained ξ_1, ξ_2 from our experiments.

Experimental dependencies of the fluctuation frequency on the flow rate for different currents and on the current for different flow rates were experimentally investigated in argon and nitrogen [4]. The investigation of the mechanism governing the rerouting (shunting) of the current path in a plasmatron channel with self-established electric arc length is performed for the axisymmetric configuration where the cathode is placed centrally and the channel wall serves as an anode. The formula was found from the analysis of the dynamics of the current channel determining the dependency of the characteristic frequency of the voltage oscillations on the external parameters of the problem: the electric arc current, the flow rate of the working gas and the characteristic diameter of the duct. This formula generalizes the results of the investigations of the voltage oscillations in the plasmatron channel with self-established electric arc length performed by different authors in a wide range of external parameters [1-4].

It follows from (2) that, according to the MHDIP, the different kinds of the dependency of voltage oscillation frequency on the flow rate may be observed. Under the greater values of the MHDIP ($N = jBd/P >> 1$) the characteristic frequency of voltage oscillation falls with

the increase of the flow rate. If the MHDIP is much less than 1 the characteristic frequency of voltage oscillation grows with the increase of the flow rate and practically doesn't depend on the current.

Fig. 1 Non-dimensional frequency f^* on the current for



different gas flow rates

The dependency of the non-dimensional frequency $f^* \equiv f(I^2\mu_0/Gd)^{-1} = (\xi_1 + \xi_2 / N)$ on the current for different flow rates of a plasma-forming nitrogen is presented in the fig. 1. For analyzing the fluctuations in plasmatron, one should take into account that for high currents the influence of the current-convection instability [6,7] might be more significant making the arc-conducting channel pulsate.

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